Electrostatic Screen for Transport of Martian and Lunar Regolith. C. Immer[1], J. Starnes[1], M. Michalenko[2], C.I. Calle[2], M.K. Mazumder[3]. [1]ASRC Aerospace, ASRC-10, Kennedy Space Center, FL 32899, [2]Electrostatics and Surface Physics Laboratory, NASA, Kennedy Space Center, FL 32899, [3]Department of Applied Science, University of Arkansas at Little Rock, Little Rock, AR 72204.

Introduction: The Martian and Lunar Regolith contain fine particulate including those in the size range from 0.5 to 200 micron [1-2]. Martian dust can be transported and deposited by Aeolian processes, including "Dust Devils". Due to the ultra high vacuum (10e-12 Torr), transport of dust on the Moon is solely a result of collision/ballistic motion. Dust obscuration of solar cells is one of the primary factors limiting the duration of Martian missions, including the Mars Exploration Rovers. Dust contamination in vacuum seals is one of the primarily factors that limited lunar excursions during the Apollo missions. Controlled transportation of dust on Mars and the Moon is important for many reasons, including both contamination mitigation and in situ resource utilization (ISRU). Since both the monopole and dipole electrostatic moments result in non-trivial forces on particles in an electrostatic field, dust particles, whether charged or not, can be transported by electrostatic fields. In the electrostatic screen, alternating waveforms of voltage applied to patterned grids of electrodes will transport dust. The authors will show that the canonical methods for transporting dust via electrostatic screen can be readily applied to transport of Martian and Lunar regolith. Experiments have been performed in ambient, low humidity, Martian, and Lunar conditions. Screen parameters have been examined for application to each regolith, such as grid spacing, trace width, grid voltage, pulse pattern, pulse frequency, and coating type. The authors have also developed an electrostatic screen based on optically transparent conductors that can be placed over solar arrays, windows, visors, lenses, etc.

Experimental Work: For testing in the laboratory, three phase, copper-conductor screens are fabricated using normal circuit board manufacturing techniques. Waveforms to apply to the screens are generated with National instruments LabVIEW software along with a PCI-6723 12 bit 32 channel analog outboard. The signals are then routed into three Matsusada AS-1.5B2 high voltage amplifiers, one for each phase. This setup allows arbitrary high voltage waveforms to be applied independently to each of the three phases on the screen. The test fixture allows rapid replacement of the screen via four support pins that also provide the electrical connection to the screen phases.

Figures 1 and 2 show a test electrostatic screen before and after it has been energized. These screens are three-phase, half-ounce copper conductors that are 0.005" wide, 0.04" apart.

Figure 1 Three phase copper screen before energizing. with JSC-1 Mars Simulant in center of screen.Figure 1.

Figure 2. Screen from figure 1 after energizing.

In addition to copper conductor screens, Indium Tin Oxide coated polyester screens have been fabricated in-house that are optically transparent. The transparent screens are readily applied over solar panels with minimal degradation in performance. Transparent screens may also be applied over viewports, visors, or windows. Figures 3 and 4 show a transparent screen before and after clearing of Mars JSC-1 Simulant[3]. To first order, clearing behavior of the transparent screens is identical to that of the copper traced screens.

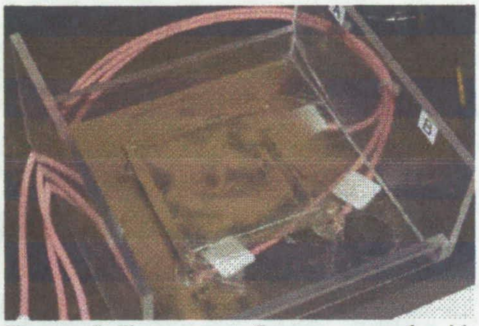

Figure 3 Transparent Screen covered with Mars JSC-1 Simulant.

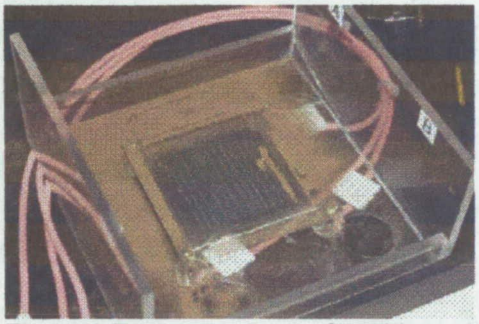

Figure 4 Transparent Screen from Figure 3 after energizing. The solar panel below the screen is revealed.

To quantify the behavior of screens, a clearing factor is defined in the following way. Approximately 0.02 grams of dust are added in a uniform thickness to the center of the screen. After energizing, the mass remaining on the screen is measured. This is subtracted from the initial mass added to the screen before energizing. The percentage mass of dust that has been removed from the screen, not including the edges, is called the "clearing factor". Clearing factor can be used to judge the performance of the screen while changing peak voltage, operating frequency, pulse patter, coating thickness, line spacing, line width, atmosphere (Terrestrial, Martian, Lunar), etc.

Results and Discussion: An sample experimental result is shown in Figure 5. In this case, the experiment was clearing factor vs. peak applied voltage. The experiment was with 0.005" Copper Traces, 3 Phase, 0.02" Grid Spacing, 10 Hz, Moesner and Higuchi pattern, Mars JSC-1 Simulant. Assuming some small residual charge on each dust particle, the force applied decreases with decreasing voltage. It is somewhat intuitive that clearing factor should also decrease with decreasing voltage. What is not immediately obvious is the dip in clearing factor at 300 volts. This dip in clearing factor at this voltage is a resonance with the switching of the phases of the screen causing the dust to oscillate between adjacent traces and never to be cleared. The only clearing occurs from those dust particles near the edges of the screen. Data for most conceivable dominate factors have been tested in terrestrial, Lunar, and Martian atmospheres. Optimization of parameters in each atmosphere is non-trivially distinct. Performance differences are mostly attributed to varying ambient pressure dominating Paschen breakdown, fluid viscosity, and dust charging.

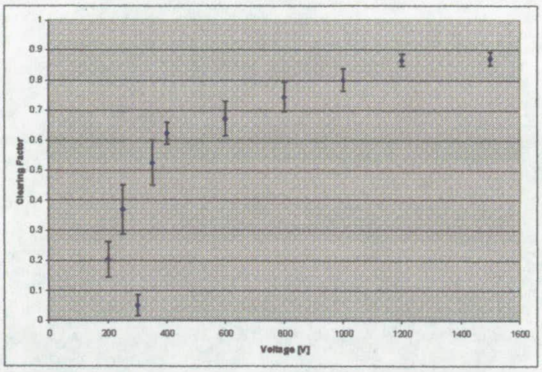

Figure 5 Clearing Factor vs. Peak Voltage for: 0.005" Copper Traces, 3 Phase, 0.02" Grid Spacing, 10 Hz, Moesner and Higuchi pattern, Mars JSC-1 Simulant.

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